

AN ELECTROPHORETIC DISPLAY

AND A METHOD OF DRIVING SAID DISPLAY

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an electrophoretic display and a method of driving said display, and more specifically to a method of selectively driving an electrophoretic display in a reflective mode or a direct-viewing display mode.

2. Description of Related Art

E-books have been developed recently, and many people prefer e-books to traditional books. An e-book uses a plane display screen to display digitally generated text so a person can read the e-book. The e-book has lots of advantages over conventional books, but the e-book has not been universally accepted. One reason the e-book has not been universally accepted is power-consumption. The plane display screen needs power to display text. When the power is turned off, the text disappears from the screen. Furthermore, a person must learn how to use the e-book. A method of conserving power while extending the persistence of the text on the screen is needed.

The power-consumption problem has been solved, and most people already know how to read an e-book, PDA, etc. The power-consumption problem was solved with the development of e-paper. E-paper is a reflective electrophoretic display material.

A company named E Ink developed a specific display material for the reflective electrophoretic display with embedded electronic ink. The electronic

1 ink's principal components are millions of tiny microcapsules, about the
2 diameter of a human hair. With reference to Fig. 17A, each microcapsule (70)
3 comprises multiple positively charged white particles (71) and multiple
4 negatively charged black particles (72) suspended in a clear fluid (73). The
5 microcapsule (70) has a top (not numbered) and a bottom (not numbered).
6 When a voltage is applied to a microcapsule (70) with a negative potential
7 applied to the top of the microcapsule (70) and a positive potential applied to
8 the bottom of the microcapsule (70), the positively charged white particles (71)
9 move to the top of the microcapsule (70), and the negatively charged black
10 particles (72) move to the bottom of the microcapsule (70). The positively
11 charged white particles (71) at the top are visible to a person and block the
12 negatively charged black particles (72). That is, the top of the microcapsule (70)
13 appears white, and the negatively charged black particles (72) are hidden. With
14 reference to Fig. 17B, reversing the polarity of the voltage applied to the
15 microcapsule (70) causes the negatively charged black particles (72) to move to
16 the top of the microcapsule (70) and the positively charged white particles (71)
17 to move to the bottom and make the microcapsule (70) appear dark. The E Ink
18 claims that their e-paper can be read under direct sunlight and has advantages
19 of high contrast, low power, wide field of vision, etc.

20 The Xerox company has also proposed a display principle similar to E
21 Ink's. With reference to Fig. 18A, multiple rollers (81) are mounted on a single
22 electrode plate (80). Each roller (81) has a black hemisphere (not numbered)
23 and a white hemisphere (not numbered). The black hemisphere has a positive
24 electric charge (+), and the white hemisphere has a negative electric charge (-).

1 When a negative electric potential is applied to the electrode plate (81), the
2 black hemispheres of the rollers (81) face the electrode plate (80). On the other
3 hand, when a positive electric potential is applied to the electrode plate (80),
4 the white hemispheres of the rollers (81) face the electrode plate (80), as shown
5 in Fig. 18B.

6 With reference to Fig. 19, the IBM company has developed an
7 electrophoretic display also composed of two electrode plates (91, 92), a
8 colored fluid (90) between the two electrode plates (91, 92) and multiple
9 colored charged particles (93) suspended in the colored fluid (90). The
10 operation of the electrophoretic display is similar to the forgoing descriptions
11 and is not further described.

12 The examples of electrophoretic displays described have the following
13 common features.

14 1. All the displays are reflective and display text by reflecting light in
15 the environment.

16 2. Low power.

17 3. High contrast.

18 4. Clear image.

19 The forgoing features of e-paper are advantages, but the e-paper display cannot
20 display clear text or images when the reflective display is used in an
21 environment with weak light.

22 The present invention provides an electrophoretic display that has
23 reflective or direct-viewing display mode to mitigate or obviate the
24 aforementioned problems of the conventional methods.

SUMMARY OF THE INVENTION

An objective of the present invention is to provide an electrophoretic display that can selectively be a reflective display, a direct-viewing display or a combination reflective and direct-viewing display.

Other objectives, advantages and novel features of the invention will become more apparent from the following detailed description when taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a side plan view in partial section of a first embodiment of an electrophoretic display pixel in accordance with the present invention;

Figs. 2 is a top plan view of a first embodiment of transparent electrodes of the electrophoretic display in accordance with the present invention;

Fig. 3 is a top plan view of a second embodiment of the transparent electrodes of the electrophoretic display in accordance with the present invention;

Fig. 4 is a top plan view of a third embodiment of the transparent electrodes of the electrophoretic display in accordance with the present invention;

Fig. 5 is a side plan view of a first embodiment of a colored particle for the electrophoretic display in accordance with the present invention;

Fig. 6 is a side plan view of a second embodiment of the colored particle for the electrophoretic display in accordance with the present invention;

Fig. 7 is an operational side plan view in partial section of the

1 electrophoretic display in Fig. 1 displaying a single black color;

2 Fig. 8 is an operational side plan view in partial section of the
3 electrophoretic display in Fig. 1 displaying a single white color;

4 Fig. 9 is an operational side plan view in partial section of the
5 electrophoretic display in Fig. 1 displaying light and black colors;

6 Fig. 10 is a side plan view in partial section of the electrophoretic
7 display in Fig. 1 with a backlit module in accordance with the present invention;

8 Fig. 11 is a side plan view in partial section in partial section of a
9 second embodiment of the electrophoretic display in accordance with the
10 present invention;

11 Fig. 12 is an operational side plan view in partial section of the second
12 embodiment of the electrophoretic display in Fig. 11;

13 Fig. 13 is a side plan view in partial section of a third embodiment of
14 the electrophoretic display in accordance with the present invention;

15 Fig. 14 is a top plan view of a fourth embodiment of the transparent
16 electrodes with a reflective layer in accordance with the present invention;

17 Fig. 15 is an operational side plan view of the electrophoretic display in
18 Fig. 13;

19 Fig. 16A is a cross sectional side plan view of the reflective layer of the
20 electrophoretic display in accordance with the present invention;

21 Fig. 16B is a side plan view of a fifth embodiment of the transparent
22 electrodes with a reflective layer in accordance with the present invention;

23 Fig. 16C is a top plan view of a sixth embodiment of the transparent
24 electrodes with the reflective layer in accordance with the present invention;

1 Fig. 16D is a top plan view of a seventh embodiment of the transparent
2 electrodes with the reflective layer in accordance with the present invention;

3 Fig. 17A is a side plan view of a first conventional electrophoretic
4 display in accordance with the prior art;

5 Fig. 17B an operational view of the first conventional electrophoretic
6 display of Fig. 17A;

7 Fig. 18A is a side plan view of a second conventional electrophoretic
8 display in accordance with the prior art;

9 Fig. 18B is an operational view of the second conventional
10 electrophoretic display of Fig. 18A; and

11 Fig. 19 is a side plan view of a third conventional electrophoretic
12 display in accordance with the prior art.

13 DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

14 An electrophoretic display (EPD) in accordance with the present
15 invention has a reflective and direct-viewing display mode or a direct-viewing
16 display mode. The EPD has multiple positively and/or negatively charged
17 colored particles, two substrates each having multiple electrodes, wherein
18 reflective and transmissive areas could be all defined on one of the two
19 substrates or respectively on the two substrates. When applying opposite
20 polarity of the voltage to at least two electrodes on the substrates, the charged
21 colored particles are moved to the reflective areas or transmissive areas. That is,
22 the charged color particles on the reflective areas or transmissive areas can be
23 controlled whether the front light is reflected by the reflective area or not, or
24 whether the backlight passes through the EPD or not. Therefore, by controlling

1 the applied polarity of voltage, the EPD can be operated in a reflective display
2 mode if the surrounding light is sufficient, or in a direct-viewing display mode
3 when the surrounding is dim.

4 With reference to Fig. 1, each pixel of a first embodiment of the EPD in
5 accordance with the present invention includes a first substrate (10), a second
6 substrate (20), colored charged particles (31, 32) and fluid (33). The fluid (33)
7 between the first and second substrates (10, 20) can be transparent or colored.
8 The colored charged particles has dark and white colored charged particles (31,
9 32) that are suspended in the fluid (33).

10 The first substrate (10) can be made of a transparent material such as
11 glass or plastic etc.. In this preferred embodiment, the first substrate (10) has an
12 outer face (101) and an inner face (102). The outer face (101) to which the
13 front light from the front light module (not shown) passes through is a front
14 face of the EDP for displaying images or text etc.. The front light module can
15 be mounted on the front face. A first transparent electrode (11) is printed on the
16 inner face (102) and has at least one first transparent electrode layer (11). The
17 first transparent electrode layer (11) can be defined as the reflective area by
18 collecting enough dark or white colored particles (31, 32).

19 The second substrate (20) can be made of a transparent or opaque
20 material such as glass, plastic and stainless steel etc.. In this preferred
21 embodiment, the second substrate (20) is transparent and parallel with the first
22 substrate (10). The second substrate (20) has an inner face (202) and an outer
23 face (201) defined as a rear face of the EDP. The inner face (202) is faced to the
24 inner face (102) of the first substrate (10). The second transparent electrode (21)

1 has at least two second transparent electrode layers (211, 212, 213). In this
2 preferred embodiment, three second transparent electrode layers (211, 212, 213)
3 are printed on inner face (202) of one pixel of the second substrate (20) and two
4 transmissive areas each is defined between the two second transparent
5 electrode layers (211, 212, 213).

6 To increase brightness of the EDP in the direct-viewing display mode,
7 with further reference to Fig.10, a backlit module (40) is adapted to mount to
8 the rear face (201) of the EPD. The backlight radiated from the backlit module
9 (40) can pass through the transmissive areas to the front face (101). The backlit
10 module (40) can be an EL (electro luminescent), PLED (polymeric light
11 emitting diode) or OLED (organic light emitting diode).

12 With reference to Figs. 2 and 3, three second electrode layers (211, 212,
13 213) of the first embodiment of the EDP are parallel with each other and each
14 second electrode layer (211, 212, 213) can be formed as a long narrow strip
15 shape or a substantially < shape. With reference to Fig. 4, one pixel of the
16 second substrate (20) has two second electrode layers (211, 212), one is a
17 rectangular frame and the other is a square shape in the rectangular frame. The
18 two second electrode layers (211, 212) are period arrangement. These examples
19 are only one part of useful shapes for the second electrode layers.

20 The dark and white colored charged particles (31, 32) filled between
21 the first and second substrates (10, 20) respectively have positive or negative
22 charge. In the first preferred embodiment of Fig. 1, the EPD has positively
23 charged black particles (31) and negatively charged white particles (32)
24 between the first and second substrates (10, 20). With reference to Fig. 5, the

1 EPD also can use microcapsules (30). Each microcapsule (30) has a transparent
2 capsule (not numbered) in which clear fluid (33) and colored charged particles
3 (31, 32) are contained. With reference to Fig. 6, the EPD uses rollers (30').
4 Each roller (30') is composed of a white hemisphere (31') and a dark
5 hemisphere (32'). The white hemisphere (31') possess a positive electric charge
6 (+), and the black hemisphere (32') possess a negative electric charge (-).

7 The forgoing description discloses a basic structure of the EPD. The
8 following means for driving the EPD is used to the forgoing EPD to make the
9 EPD to have a reflective and/or a direct viewing display mode or a direct
10 viewing display mode.

11 (1) Reflective display mode of the EPD:

12 With reference to Fig. 7, a negative potential voltage and a positive
13 potential voltage are respectively applied to the first and second electrode
14 layers (11, 211, 212, 213) of the EDP. The positively charged black particles
15 (31) are moved and collected to the first electrode layer (11) and the negatively
16 charged white particles (32) are moved and collected to the second electrode
17 layers (11, 211, 212, 213). Therefore, the reflective area is established on the
18 first substrate (10) by collecting these positively charged black particles. That is,
19 the front face displays dark spot because the front light is not reflected by the
20 black charged particles and the backlight is blocked not to pass through the first
21 substrate (10).

22 With reference to Fig. 8, reserving the potentials of voltages applied to
23 the first and second electrode layers (11, 121, 122, 123) causes the negatively
24 charged white particles (32) to be moved and collected to the first electrode

1 layer (11) and the positively charged black particles (32) to be moved and
2 collected to the second electrode layers (211, 212, 213). The front face displays
3 light spot because the front light is reflected by the negatively charged white
4 particles that is collected to the first electrode layer (11).

5 (2) Direct viewing display mode of the EPD:

6 With reference to Fig. 9, the means for driving the EDP is
7 accomplished by applying a negative and a positive potential voltages to the
8 second electrode layers (211, 212, 213). That is, the positive potential voltage is
9 applied to the two second electrode layers (211,213) and the negative potential
10 voltage is applied to the one second electrode layer (212). All the white and
11 black particles (31,32) are connected to the three second electrode layers (211,
12 212, 213). Each transmissive area is defined between two of the second
13 electrode layers (211 to 213) so the backlight can pass through the second and
14 first substrates. The EPD display light spots.

15 With reference to Fig. 11, a second embodiment of the EPD in
16 accordance with the present invention is similar to the first embodiment. In the
17 second embodiment, a first electrode (11) has three first electrode layers (111 to
18 113) printed on an inner face (not numbered) of the first substrate (10). Each
19 first electrode layers (111, 122, 113) is aligned with the corresponding second
20 electrode layers (211 to 213). Therefore, one pixel of the EPD has three pairs of
21 first and second electrode layers (111, 211) (112, 212) (113, 213).

22 The means for driving EPD further uses a positive potential voltage and
23 a negative potential voltage to apply to one pair of the first and second
24 electrode layers (112, 212). With reference to Fig. 12, when the first electrode

1 layer (112) is connected to the positive potential voltage and the second
2 electrode layer (212) is connected to the negative potential voltage, the black
3 and white particles (31, 32) are respectively collected to the pair of the first and
4 second electrode layers (112, 212). The other two pairs of the first and second
5 electrode layers (111, 211) (113, 213) do not collect any particles (31, 32) so
6 more backlight can pass through the second substrate (20) to the first substrate
7 (10). Therefore, the front face (101) is brighter than the first embodiment of the
8 Fig. 10.

9 With reference to Fig. 13, a third embodiment of the EPD in
10 accordance with the present invention is similar to the second embodiment of
11 Fig. 11. The third embodiment of the EPD comprises a first substrate (10), a
12 second substrate (20), three first electrode layers (111 to 113) formed on the
13 first substrate (10), two second electrode layers (211, 212) formed on the
14 second substrate (20), a reflective layer (51) formed on the second substrate (20)
15 on which the second electrodes do not formed (as shown in Fig. 14), and
16 multiple single colored (black) charged particles (31).

17 The two second electrode layers (211, 212) are parallelly formed on the
18 second substrate (20). The first electrode layers (111 to 113) are not aligned
19 with the second electrode layers (211, 212). The second electrode layers (211,
20 212) are transparent so the second electrode layers (211, 212) are defined as
21 transmissive areas of EPD. The reflective layer (51) is made of multiple films
22 with high reflectance.

23 With reference to Fig. 13, when all black charged particles (31) are
24 collected to the second substrate (20), the backlight can not pass the

transmissive areas and the front light is not reflected upward by the black charged particles (31). Therefore, the front face of the EPD displays dark spot.

With reference to Fig. 15, an electric filed is applied to the three first electrode layers (111 to 113) and the black charged particles (31) are collected on the first electrode layers (111 to 113). The front light passes through the first substrate between two of the first electrode layers (111 to 113) and then is reflected upward by the reflective layer (51). In addition, the backlight also passes through the second substrate (20) to the first substrate. Therefore, the front face (101) of the EPD displays bright spots.

To increase the brightness of the front face (101) the reflective layer (51) has an upper face (511). With reference to Fig. 16A, the upper face (511) can be processed to be diffusive or random wave shaped to provide a scattering capability. The upper face (511) can be a flat as a mirror. With reference to Fig. 16B, the second electrode layers (211) and the reflective layer (51) are alternately formed on the second substrate (not shown). With reference to Fig. 16C, each second electrode layer (211) is circle formed on the second substrate (not shown) and the reflective layer (51) is formed on the second substrate which is not covered by the second electrode layers (211). With reference to Fig. 16D, the three second electrode layers (211) are paralleled to each other on the second substrate and the reflective layer (51) is formed on the second substrate.

Based on the forgoing description, the present invention discloses an EPD having reflective and direct-viewing display modes by selectively controlling a driving means of the EPD. That is, the EPD can become reflective

1 display or a direct-viewing display. When the EPD in sunshine environment,
2 the EPD has enough front light to display so the EDP uses the reflective display
3 mode. On the other hand, when the EPD in light weak environment, the EPD
4 can drive the backlight module to provide a backlight and uses the direct-
5 viewing display mode. Therefore, the present invention can provide high
6 quality of display information or image whether the light is enough or not.

7 Even though numerous characteristics and advantages of the present
8 invention have been set forth in the foregoing description, together with details
9 of the structure and function of the invention, the disclosure is illustrative only,
10 and changes may be made in detail, especially in matters of shape, size, and
11 arrangement of parts within the principles of the invention to the full extent
12 indicated by the broad general meaning of the terms in which the appended
13 claims are expressed.